

V. *Essay on a new Method of applying the Screw.* By Mr. William Hunter, Surgeon; communicated by Lieutenant General Melville, F. R. S.

Read December 21, 1780.

I HAVE some time ago been led to think, that the screw, which of all the mechanical powers is the most commonly employed in performing motions which require great accuracy, might be applied in a manner which would better answer many intentions than that commonly used. The plan is somewhat similar to NONIUS's division of the circle; but before I explain myself farther it may be proper to lay down a few general rules on which we may found a comparison.

The perfection of any machine consists in accomplishing the end proposed in a manner the most effectual, the most expeditious, and the least cumbersome possible. In order to attain this end the following things are required.

1. That the strength of the several parts of the engine be so adjusted to the force they are intended to exert, as that they shall not break under the weight they ought to counteract, nor yet encumber the motion by a greater quantity of matter than is necessary to give them a proper degree of strength.

2. That the increase of power, by means of the machine, be so regulated, that while the force we can exert is thereby rendered adequate to the effect, it may not be retarded in procuring it more than is absolutely necessary.

3. That

3. That the machine be as simple as is consistent with other conditions.

4. That it be as portable and as little troublesome in the application as possible.

5. That the contrivance be such that the moving power may be applied in such a way as to act to the greatest advantage; and that the motion ultimately produced may have that direction and velocity which is most adapted to the execution of the design proposed by the whole.

6. Of two machines, equal in other respects, that deserves the preference in which the friction least diminishes the effect proposed by the whole.

It will easily appear, that some of these conditions, if carried to an extreme, will be inconsistent with some of the others. Here the proper medium consists in adapting them to each other in such a manner, as that the result of the advantages of both may be the greatest, and that of the defects the least, that is possible.

The following method of applying the screw, I think, may in certain cases be attended with some of these advantages to a greater degree than by those commonly practised.

Let AB (fig. 1.) be a plate of metal in which the screw CD plays, having a number of threads in an inch equal to a . Within the screw CD there is a female screw, by which is received the smaller screw DE of $a + 1$ threads in an inch. This screw is retained from moving round along with the screw CD by means of the apparatus at AFGB.

Now, if the handle CKL be turned a times round the screw, CD will advance upwards an inch, and if we suppose the screw DE to move round along with CD, the point E will also advance an inch. If we now turn the screw DE a times backwards, the

point E will move downwards $\frac{a}{a+1}$ of an inch, and the result of both motions will be to lift the point E upward $(1 - \frac{a}{a+1} =) \frac{1}{a+1}$ of an inch. But if, while the screw CD is turned a times round, DE be kept from moving, the effect will be the same as if it had moved a times round with CD and been a times turned back, that is, it will advance $\frac{1}{a+1}$ of an inch. At one turn therefore of the handle CKL it will move upwards $(\frac{1}{a+1} \times \frac{1}{a} =) \frac{1}{a^2+a}$ of an inch. If then we suppose the handle CKL to be b inches long, the power gained by the machine will be as $\overline{a^2+a} \times 6,2832 \ b$ to unity.

To illustrate this by a particular example, let the screw CD have 10 threads in an inch, and DE 11 : then, while the handle CKL is turned 10 times round, the point D will rise one inch above its former situation. But at 10 turns it can only pass over 10 threads of the screw DE, and consequently it will advance upon that screw $\frac{1}{11}$ th of an inch. The point E therefore must rise $\frac{1}{11}$ th of an inch, that the point D may have room to rise a complete inch above its former place : therefore, at one turn of the handle, the point E will rise $\frac{1}{110}$ th of an inch ; and if the handle be supposed half a foot long, the power, to produce an equilibrium, must be to the weight as 1 to $110 \times 6,2832 \times 6 = 4146,912$, which is the very number expressed by the general theorem, *viz.* $\overline{a^2+a} \times 6,2832 \ b$, calling $a=10$ and $b=6$.

Now let us compare, according to the rules before laid down, this method of using the screw with the common one. And, first, in order to have the same power by means of the common screw that is exerted by this machine, it must have a number of threads

threads in an inch equal to $a^2 + a$, which would render it too weak to resist any considerable violence. For example, if DE have five threads in an inch, and DE fix, and if the handle CKL is a foot in length, the power gained by the engine will be nearly as $(\overline{a^2 + a} \times 6 b =) 2160$ to 1; whereas, to have the same force by means of the common screw, it must have 30 threads in an inch, and so must yield under a resistance which the other screw would overcome without any difficulty. Upon this principle, the screw may be applied with advantage in presses of different kinds, by fixing one of the plates of the press to the end of the screw at E.

As to the second requisite, both methods may be equally adapted to it; yet other circumstances will determine us to apply the common screw where a small increase of power is necessary, and the present contrivance, when we stand in need of a greater.

This will follow from the third rule, as in the method now proposed a double number of screws is required, which makes the structure more complicated, occasions more expence, and requires a greater accuracy of construction, since, unless this is attended to, the machine will not move.

However, the machine may, in some cases, answer the fourth intention better than the common one, as the power gained by the additional screw enables us to shorten the handle which will tend to make the whole more portable.

The power is here applied in the same direction as in the common screw, so that both equally answer the first part of the fifth rule; but as to the last, the motion *ultimately* produced, it will depend on particular circumstances which of them is most fit for use in any case. Thus, if the screw DE be intended to carry an index which must turn round at the same time that it rises upwards, the common screw is preferable; for although I

can

can see a method by which the machine before described may be made to answer this purpose, I am almost afraid to propose it. I mean, that within the screw DE another still smaller should be made to play, and be connected with the screw CD, so as to move round along with it. It must have $a^2 + a + 1$ threads in an inch, and they must be in the contrary direction to those of CD, so that when they are both turned together, and CD moves upwards, this other one may move downwards. At one turn of the handle this will move upwards $\frac{1}{a^2 + a} \times \frac{1}{a^2 + a + 1}$ $= \frac{1}{a^4 + 2a^3 + 2a^2 + a}$ of an inch, and at the same time will move round in a circular direction. For example, let CD have 5 threads ($= a$) in an inch, DE 6 ($= a + 1$), and a third screw within DE, but connected with CD so as to partake of its motion, 31 ($= a^2 + a + 1$). At one turn of the handle, this screw will rise upwards $\frac{1}{5} \times \frac{1}{6} \times \frac{1}{31} = \frac{1}{930}$ of an inch; but this appears too complicated for use, and the least inaccuracy in the construction would hinder it from moving.

But, on the other hand, if while the point E rises it is of consequence that it be kept from going round, the machine under consideration will best answer this purpose. On this principle it may be useful in several respects: for instance, let A (fig. 2.) represent a magnifying lens, and let it be moveable upon the screw BC of 16 threads in an inch, which turns within the larger screw CD of 15 threads in an inch, and that again moves within the plate EF in the end of the cylinder GF*. To use the instrument, fix the object to be magnified upon the pin GL, and then turn the lens A upon the screw BC, till it be

* The screw BC is restrained from moving along with CD by the small pillar HK, which slides backwards and forwards in a groove in the cylinder GF.

nearly at the proper distance from the pin, and opposite to it. You may then adjust the distance more accurately by turning the screw DC, at each turn of which the lens will recede from, or approach to, the pin $\frac{1}{240}$ th of an inch. This it will do and not turn aside, but still remain opposite to the pin LG. A double microscope might be fitted on in the place of the lens A. The whole instrument may be furnished with a handle, as at M; or, if larger, it may have three feet to stand on a table.

On the last principle it must be owned, the common screw has the advantage, as two screws will produce more friction than one; and, besides, in the compound engine there is an additional friction from the piece FG (fig. 1.) upon the pillars between which it moves.

Another case in which this machine may be employed is in the micrometer. Thus, let the screw AB (fig. 3.) of 50 threads in an inch be turned round by the index c, which moves upon the graduated circle ECD in the direction CD. Within the screw AB is the smaller one AF of 51 threads in an inch, retained from moving round by the bar GFH. The piece AF is continued to K, where it forms a fine point. To use the instrument, let it be adjusted to the telescope or microscope by which you are to view a star, or some small object, and let the point K appear just to touch one edge of the object. Then turn the index c, and the point K will advance upwards till it appears to cover the other edge of the object, and thus you can determine its size. The point K will advance at each complete turn of the index $\frac{1}{2550}$ of an inch; and if the circle be divided into 80 equal parts, one of which, if it is an inch in diameter, will be very observable, while the index moves over one of these, the point K will advance $\frac{1}{204000}$ of an inch.

Thus, for example, suppose I am to measure the diameter of a nervous fibre in the medullary substance of the brain, I make the point κ appear close to one edge, and turn the index till the same point pass over the fibre, and appear to touch the other edge: I then look on the graduated circle ECD , and perceive that the index c has passed over, suppose, 23,2 divisions. Hence I conclude the diameter of the fibre to be $23,2 \times \frac{1}{204000} = \frac{1}{8790}$ of an inch, which is nearly the size as found by the accurate observations of Dr. MONRO. There should be a NONIUS's scale on the index which will measure to one tenth of a division.

As the index c must continue close to the plate ECD , while at the same time it turns round the screw AB , which is continually rising, it must be made as in fig. 4. where a , b , are two small pieces which play in a groove in the screw AB (fig. 3.) while the groove cd (fig. 4.) in the index is filled up by a protuberance of the plate ECD (fig. 3.); the piece below the groove cd (fig. 4.) being sunk into that plate. The whole machinery may be inclosed in a cylinder of brass reaching from B to L (fig. 3.), so that the point of the screw KL may be without it, and the sides of the cylinder may be open at ECD .

It is farther to be observed, that what has been said goes on the supposition that the point κ , in the micrometer, is equally magnified with the object we are to measure. But, if this point be placed in the focus of the eye-glass of a double microscope; when it moves it will pass over, not the object itself, but its image, magnified by the object-glass. In this case, if the object-glass magnify the diameter 10 times, while the index passes over one division, the point κ will pass over the image of an object, the diameter of which is $\frac{1}{204000}$ of an inch. As in this mode of application the point κ must fall between the
object

object and eye-glass, the screws may be contained within the *fulcrum* by which the microscope is supported.

The machine (fig. 1.) may be applied as a jack to raise great weights a little way from the ground, by substituting two cross hand-spikes for the handle CKL; or a vertical handle may be employed in the following manner. Let A (fig. 5.) be a pinion turned by the handle AB, which we suppose a foot in length. Let the pinion A have 4 teeth, and move the wheel CD of 16 teeth. The screw EF of 4 threads in an inch is fixed in this wheel, and turns round along with it. Within it plays the screw FG of 5 threads in an inch, and which we suppose prevented from following the motion of EF: it terminates in such a shoulder as that represented at G, and being continued to H ends in a foot as in the figure. The whole is inclosed in a strong frame. The pinion A must be connected in such a manner with the wheel CD as to rise within the frame along with it, which may easily be done by making its axis play in a piece of wood or metal, which is connected by the end to the screw EF. Or, if this should be deemed inconvenient, as the rising of the pinion must raise the handle AB, the wheel CD may be hindered from rising, and at the same time turn the screw EF, by a contrivance similar to that used with the index c (fig. 3.) in the micrometer. In either case, the axis of the pinion should be continued through the opposite side of the frame, and armed with a heavy fly to regulate the motion. When the machine is to be applied to use, the bottom of the frame resting on the ground, if the body to be lifted is already as high as the top G, that top is applied below it; but if it is close to the ground, we put below it the foot H; then, if the handle AB be turned once round, the wheel CD and screw EF will turn $\frac{1}{4}$ part round, and the point F will rise ($\frac{1}{4} \times \frac{1}{4} =$) $\frac{1}{16}$ th of an inch. The point G or H will

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therefore be lifted upwards ($\frac{1}{16} \times \frac{1}{5} =$) $\frac{1}{80}$ th of an inch. But the end B of the handle AB has described above six feet; therefore the velocity of the point G is to that of the point B as one to ($72 \times 80 =$) 5760. Therefore, if we suppose a man to act at the handle with a force equal to 30 lbs. he may keep in equilibrio a weight of 172800 lbs. But a subduction of perhaps more than one half of this must be made, that he may raise the weight, as the friction of the engine will be considerable. Suppose it to be two-thirds, the effect still remains equal to 57600 lbs. or 25 tons 14 cwts. and 32 lbs.

It will easily appear, that this method of applying the screw may have a place in many other engines, particularly where great accuracy is required; or we want a motion to be performed with great power, while at the same time it need not have any large compass. The few examples given above may serve as a specimen.



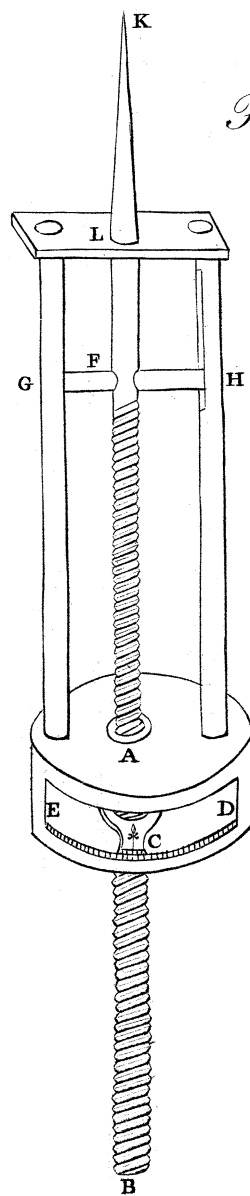
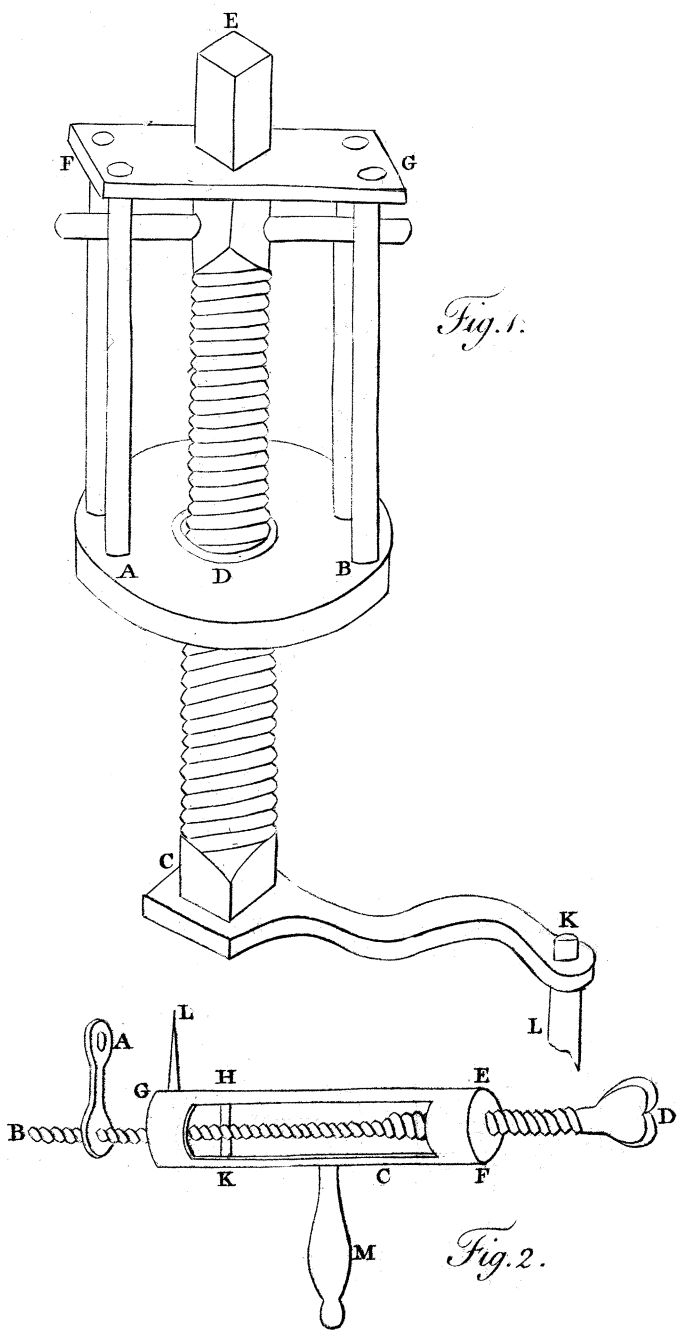


Fig. 4.

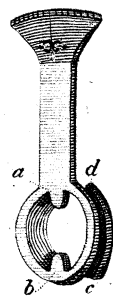
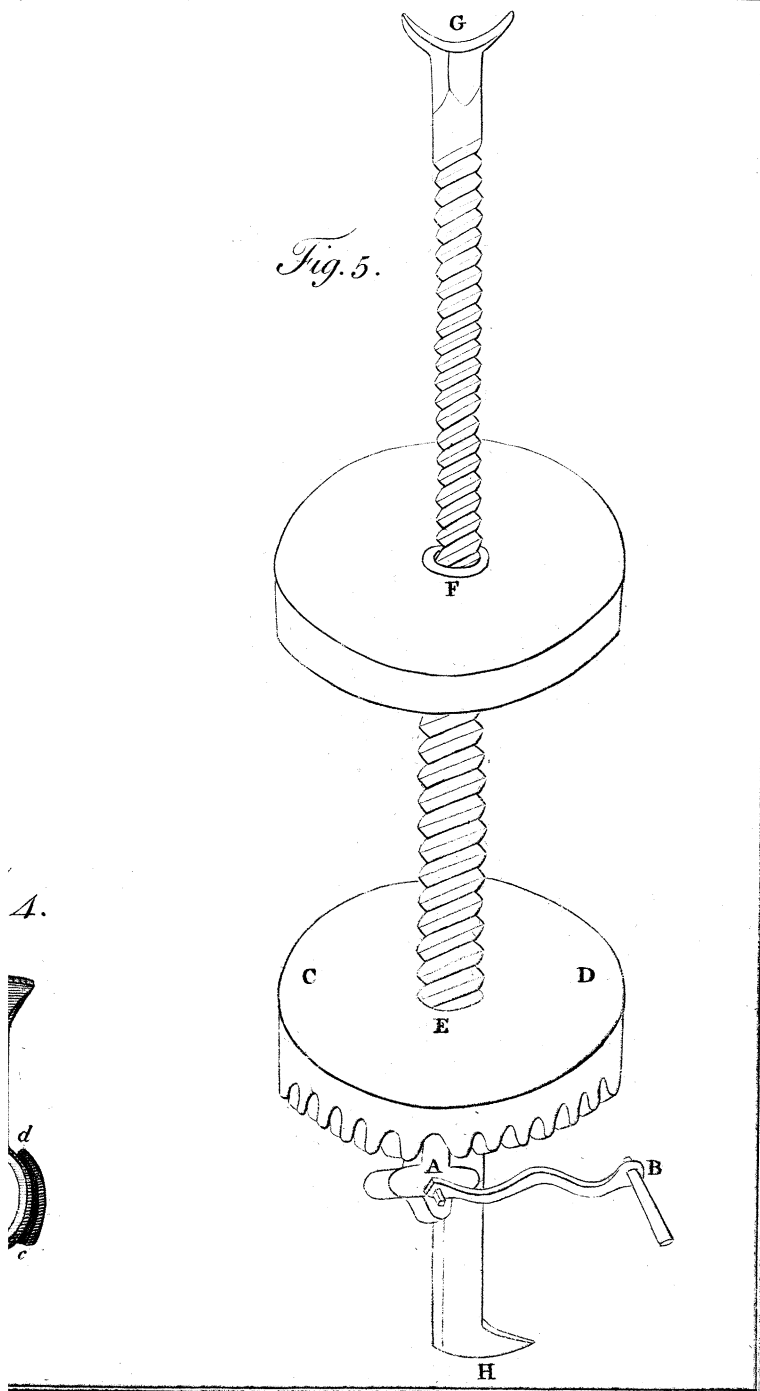


Fig. 5.



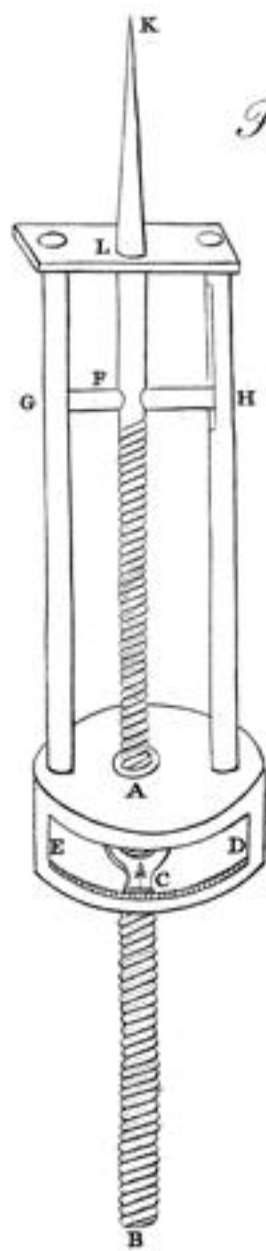
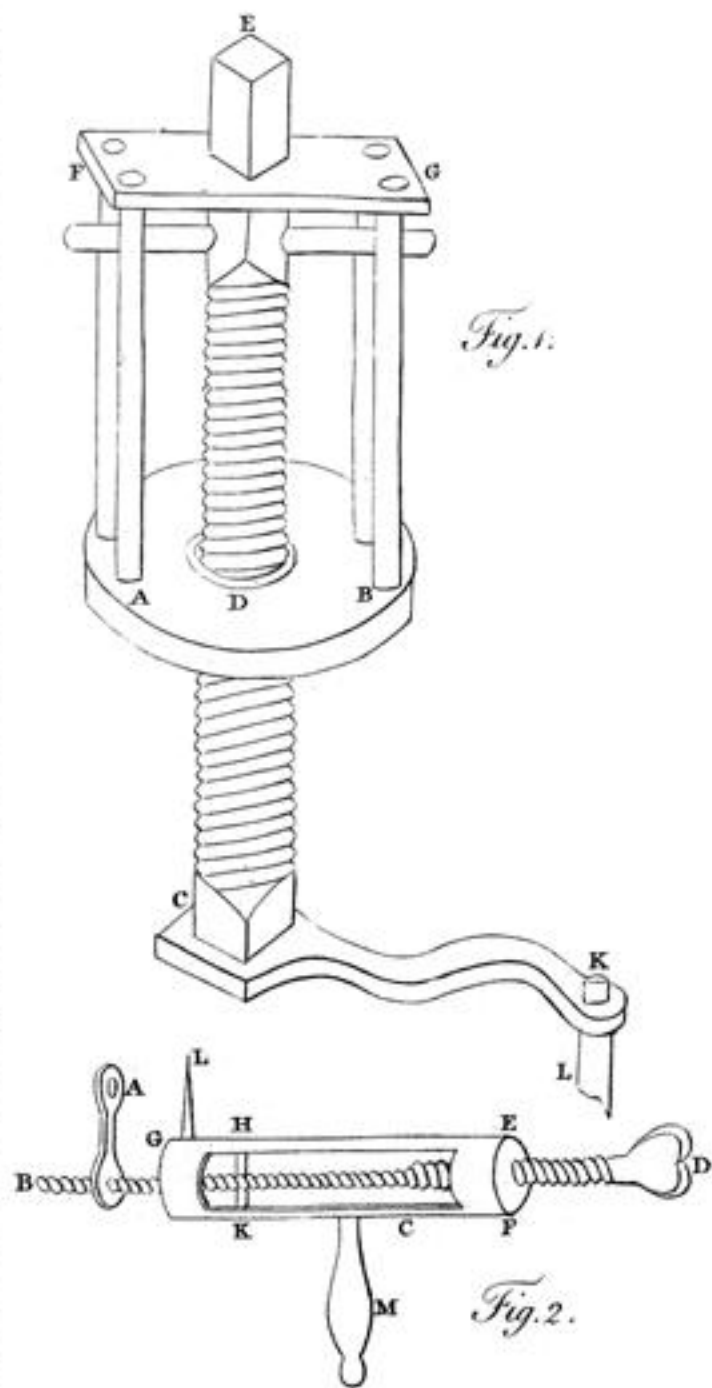


Fig. 4.

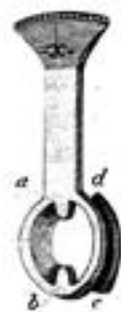


Fig. 5.

